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VERDIGRIS RIVER INVESTIGATION

AN INVESTIGATION OF THE POLLUTION OF THAT REACH OF THE VERDIGRIS RIVER BETWEEN NEODESHA, KANSAS, AND NOWATA, OKLAHOMA

ENVIRONMENTAL HEALTH CENTER
CINCINNATI, OHIO

PREPARED FOR
OKLAHOMA STATE PLANNING AND RESOURCES
BOARD, OKLAHOMA CITY

MARCH 1949

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VERDIGRIS RIVER INVESTIGATION

An investigation of the pollution of that reach of the Verdigris River between Neodesha, Kansas and Nowata, Oklahoma,

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16. Abstracts

The pollution of this section of the Verdigris River was studied to determine the cause of the taste and odor that occur from time to time in the Nowata water supply. Over 170 samples were collected and analyzed from August to October, 1948. The results do not preclude the possibility of the occurrence of a municipal sewage, algae, or decomposition of organic matter. It is concluded that continued care should be exercised by the oil refineries to isolate and impound the stronger phenolic wastes, to utilize existing treatment units to the best advantage, and to avoid spills or prevent their discharge into the river.

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Federal Security Agency
U. S. Public Health Service
Division of Water Pollution Control
ENVIRONMENTAL HEALTH CENTER
Cincinnati, Ohio
March, 1949

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U. S. PUBLIC HEALTH SERVICE

Environmental Health Center

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VERDIGRIS RIVER INVESTIGATION

An Investigation of the Pollution of That Branch of the Verdigris River between Neodesha, Kansas, and Nowata, Oklahoma

By

Graham Walton
Sanitary Engineer

Prepared by the U. S. Public Health Service in cooperation with the Division of Sanitation, Kansas State Board of Health, the Division of Sanitary Engineering, Oklahoma State Board of Health, and the Division of Water Resources, Oklahoma State Planning and Resources Board.

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VERDIGRIS RIVER INVESTIGATION

An Investigation of the Pollution of that Reach of the Verdigris River between Neodesha, Kansas, and Nowata, Oklahoma.

Introduction

In co-operation with the Division of Sanitation, Kansas State Board of Health, and the Division of Sanitary Engineering, Oklahoma State Board of Health, an investigation was made of the pollution of that section of the Verdigris River between Neodesha, Kansas, and Nowata, Oklahoma. The primary purpose was to study the cause of the taste and odor which occur from time to time in the Nowata water supply.

A previous report, dated June, 1944, was prepared by M. LeBosquet, Jr., Senior Sanitary Engineer, U. S. Public Health Service. That study, made at the request of the Chief of Engineers, U. S. Army, was prepared from data available from Federal, State and municipal sources. The report estimated the monetary benefits to water supply and waste disposal which would result if a specified minimum stream flow were to be maintained.

For the current investigation, a mobile trailer laboratory unit was located at the water filtration plant, Coffeyville, Kansas. Assisting personnel was furnished by the Division of Sanitation, Kansas State Board of Health; the Division of Sanitary Engineering, Oklahoma State Board of Health; and the Division of Water Resources, Oklahoma State Planning and Resources Board. Over 170 samples were collected from the Verdigris and Fall rivers and analyzed during the period August 24 through October 1, 1948. General surveys were made of the Standard Oil Company refinery at Neodesha, and of the Sinclair Refining Company and the Co-operative Refinery Association plants at Coffeyville. Weirs were installed in the main effluent channels at the two latter plants, and flow measurements taken and composite samples collected over several 24-hour periods, and analyzed.

It is desired to acknowledge the assistance and co-operation of the State personnel assigned to the project, of the industries, of the various municipalities and their employees, and of the Corps of Engineers and the U. S. Geological Survey.

Conclusions

(1) No difficulty occurred with taste and odor of the Nowata water supply during the period of this investigation. A comparison of the results of analyses for phenol, dissolved oxygen, biochemical oxygen demand, chlorides and chlorine demand, and of the bacteriological examination for coliform bacteria, shows the quality of the raw water at Nowata, Oklahoma, to compare favorably with that of the raw waters used at Neodesha, Independence and Coffeyville.

(2) Since stream flow and water temperature were not critical, and since no known spills occurred from any of the industrial plants during the period of this investigation, these results do not preclude the possibility of the occurrence of a taste and odor problem at Nowata due to industrial wastes, municipal sewage, algae, or decomposition of organic matter, or a combination thereof, under conditions less favorable than those occurring during this investigation.

(3) Continued surveillance of the Verdigris River from Coffeyville, Kansas, downstream to Nowata, Oklahoma, is desirable. The true cause of the taste and odor problem of the Nowata water supply can best be determined by investigations conducted during the occurrence of such a problem.

(4) As for phenolic wastes, the most critical times are during or immediately following periods of low stream flow during the late fall, winter, or early spring months. With both low water temperature and low stream flow, the river will become heavily laden with phenolic wastes. A rising stream discharge will rapidly flush this slug of waste downstream. Under such conditions the water at the Nowata intake may contain up to 40 or 50 p.p.b. of phenol, even though the phenol in the combined wastes discharged from the two Coffeyville refineries amounts to only 23.1 pounds per day.

(5) Only slight local pollution of the Verdigris River was found to occur upstream from Coffeyville, Kansas. In the vicinity of Coffeyville, increased pollution resulted from industrial wastes; and the natural recovery of the stream was retarded by the addition of raw sewage from Coffeyville. However, the data show that under conditions existing during this investigation the stream had recovered prior to reaching Nowata, Oklahoma.

(6) The natural purification processes resulted in a rapid reduction of the phenolic compounds at water temperatures (20 to 30°C.) encountered during this investigation. A phenol concentration of 60 p.p.b., the maximum mean value immediately below the downstream refinery at Coffeyville, was reduced to a mean of 9 p.p.b. three miles downstream, and to 6 p.p.b. in an additional five miles. The average phenol content of the water at the Nowata waterworks intake was 3 p.p.b., which is as low as that of any of the regular sampling stations.

(7) Continued care should be exercised by the oil refineries to isolate and impound the stronger phenolic wastes, to utilize existing treatment units to the best advantage, and to avoid spills or to prevent their discharge into the river. These precautions are especially important during late fall, winter, or early spring periods of low stream flow.

Description

The Verdigris River is 351 miles long from its source in Chase County, Kansas, to its confluence with the Arkansas River near Muskogee, Oklahoma. It flows in a generally southerly direction for a distance of 189 miles in Kansas and 162 miles in Oklahoma, and drains a total of 8,150 square miles.

The basin area, with which this report is concerned, consists of the watershed tributary to the Verdigris River at the Nowata, Oklahoma, water plant. It has an area of 4,003 square miles. The greater portion of this watershed is an undulating plain which falls steeply toward the valley. There is a rapid runoff from the tributary streams. This not only causes frequent floods, but also results in extended periods of low flow. The principal tributaries are the Fall and Elk rivers, which enter into the Verdigris River from the west, 215 and 198 miles, respectively, above its mouth.

The population of this watershed is approximately 100,000. The largest cities, both of which are in Kansas, are Coffeyville with 18,000 and Independence with 11,000. Farming and stock raising are of primary importance, and there are numerous oil and gas wells in the basin. The major industry is the refining of oil.

The field investigation upon which this report is based has been limited to that reach of the Verdigris River which extends from Neodesha, Kansas, to Nowata, Oklahoma. It is a section which has had a long history of pollution from oil fields and refineries as well as from normal domestic sewage and miscellaneous industrial wastes. Here the channel swings back and forth across the valley in well-defined banks. The fall of the channel is approximately 1.5 feet per mile and only occasional obstructions, such as low dams or minor gravel bars, are found. During periods of low flow (100 cubic feet per second or less) the stream is sluggish and has an estimated average velocity of 0.5 feet per second or less. For the most part the banks, which are 10 to 40 feet in height, are covered above low water line with a heavy growth of timber and vegetation.

The only cities which discharge domestic sewage and industrial wastes into the Verdigris River within the reach investigated, are Coffeyville, Independence and Neodesha in Kansas, and Nowata in Oklahoma. Wastes from two other communities, Fredonia on the Fall River and Cherryvale on Drum Creek, might have a slight effect on the pollution of the section of the Verdigris River studied. The principal sources of industrial wastes which may be of concern are the three oil refineries: the Standard Oil Company of Indiana refinery at Neodesha, and the Sinclair Oil

Company and the Co-operative Refinery Association refineries, both at Coffeyville. Still other oil pollution possibilities are drainage from oil and gas wells and leakage from pipe lines which cross the river.

Presentation of Data

Figure 1 shows the location and magnitude, as indicated by biochemical oxygen demand, of the principal sources of pollution; the location of the intakes and the volume of water withdrawn for municipal and industrial supplies; and a graphical summary of the variations in dissolved oxygen, biochemical oxygen demand, and phenol, throughout the reach of the Verdigris River investigated.

The mean results of the chemical analyses and bacteriological examinations of all the samples collected from each station on the Verdigris and Fall rivers are given in Table 4, and a complete tabulation of the laboratory results on the individual samples may be found in Table 7, Appendix A.

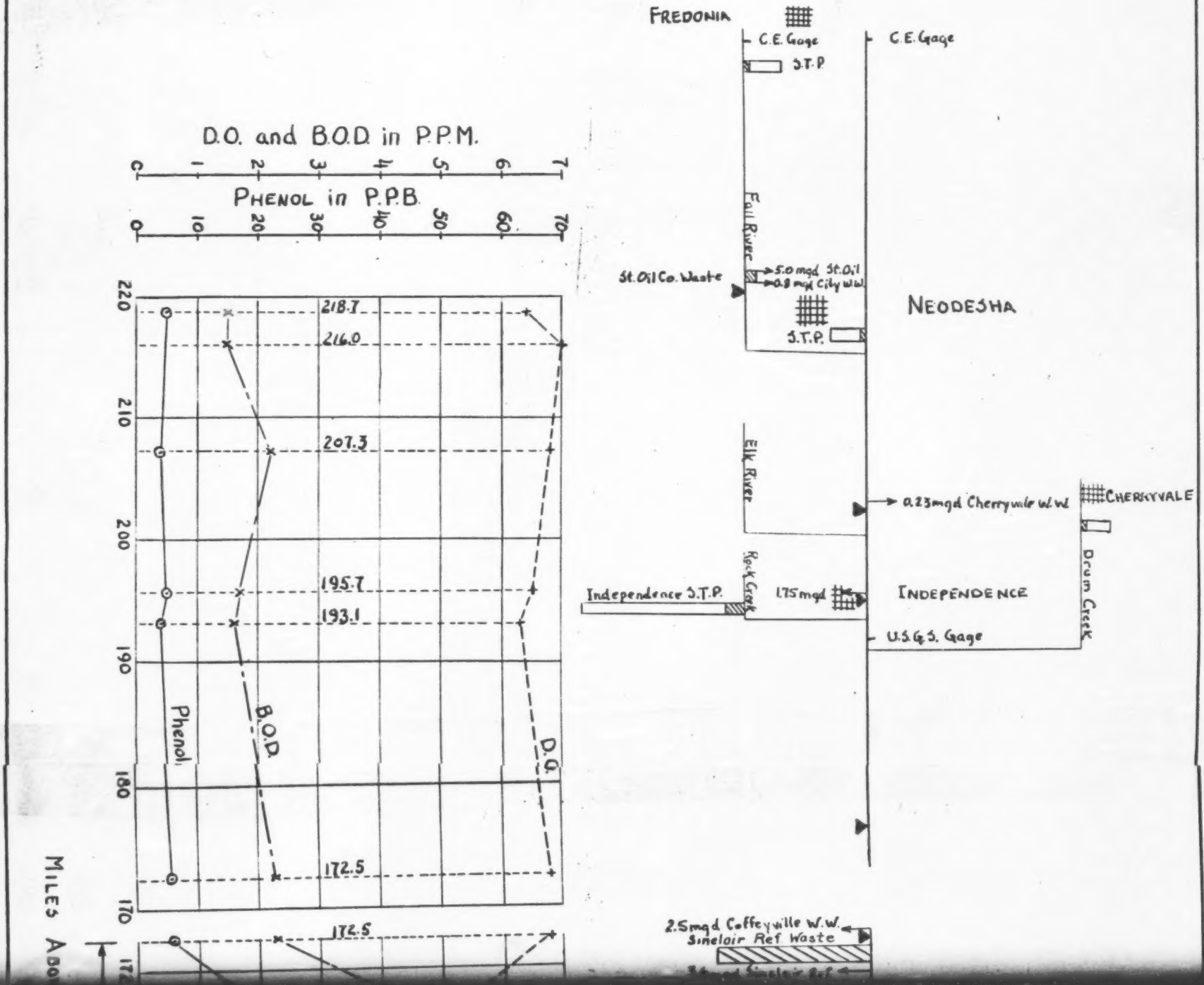
Municipal Water Supplies

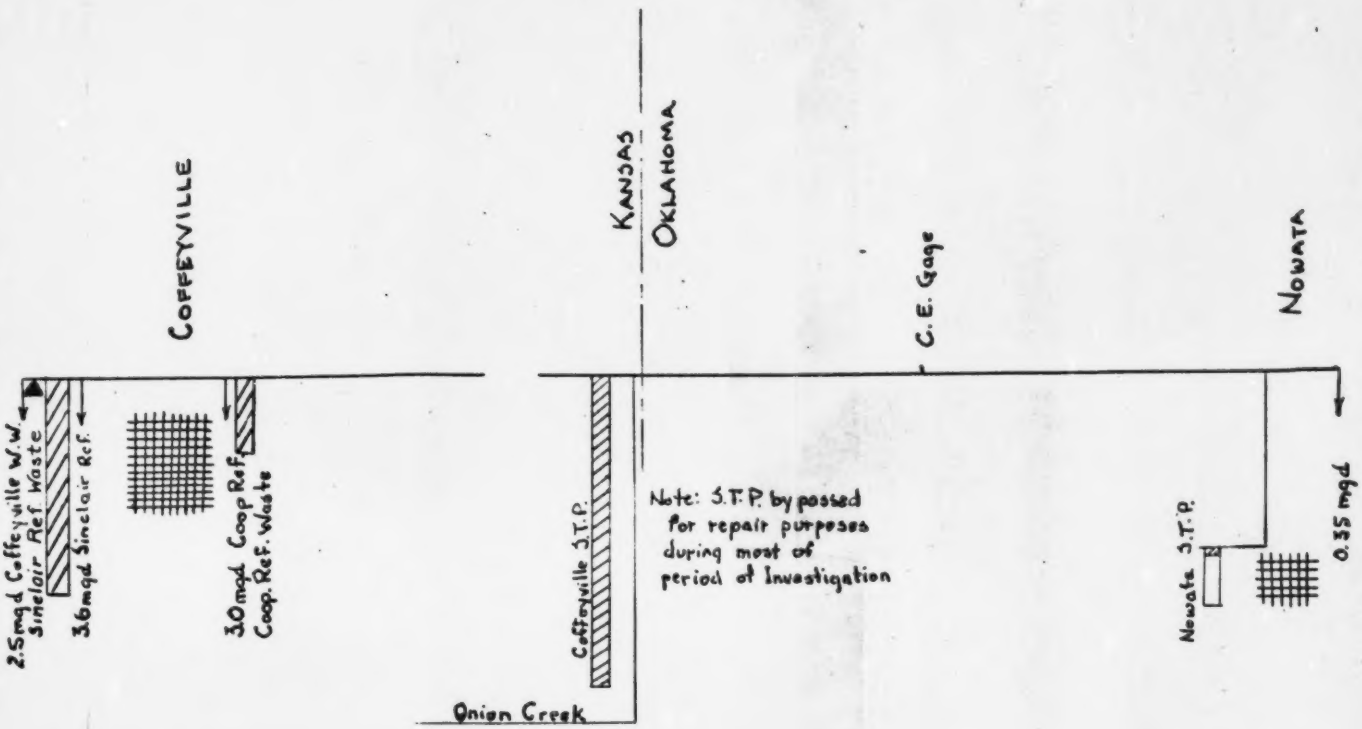
Municipal water supplies taken from the Verdigris and Fall rivers within the reaches investigated are given in Table 1, data for which were furnished by the states and summarized by the Public Health Service in the "Inventory of Water and Sewage Facilities in the United States, 1945."

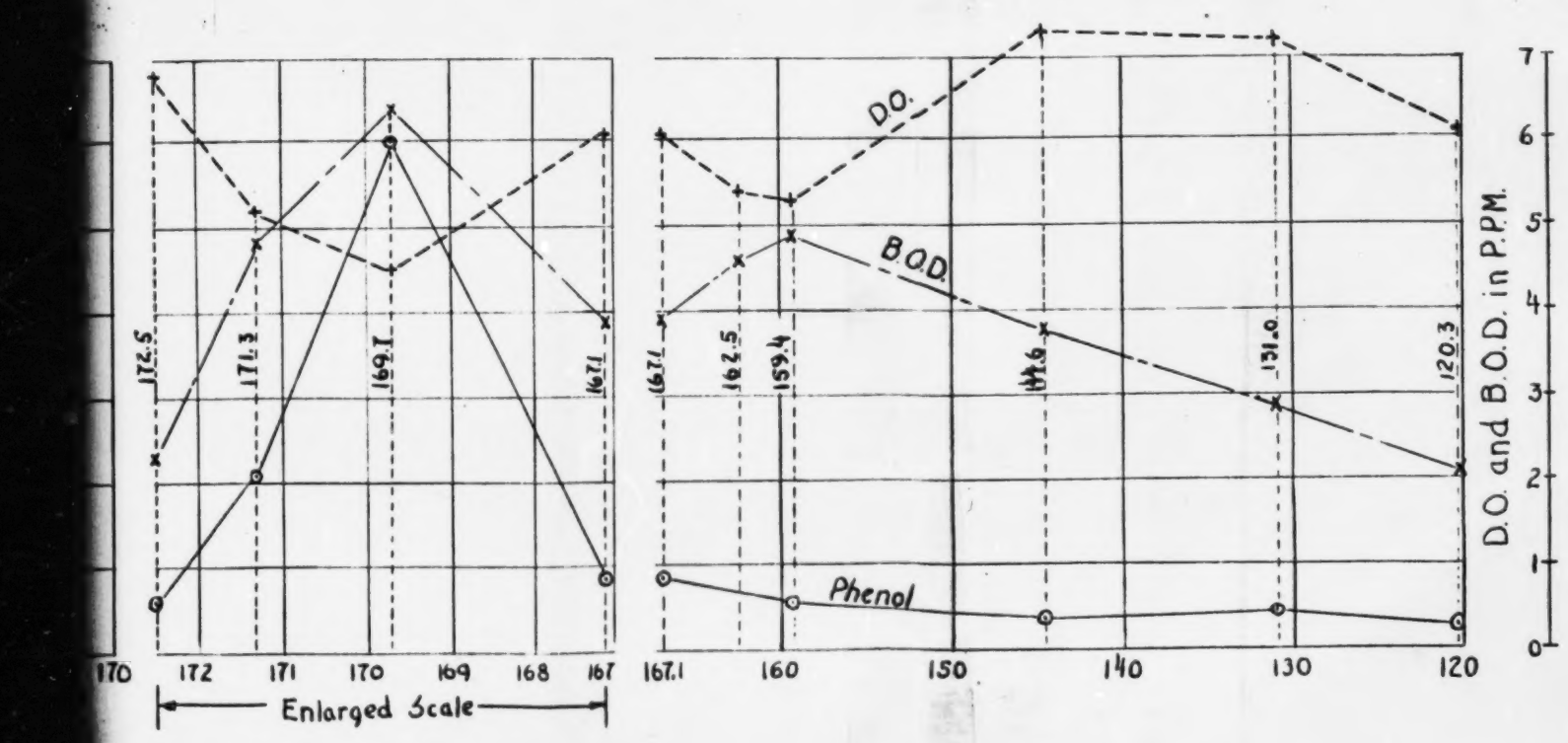
Four of these municipalities draw water from Verdigris River, and one, Neodesha, secures water from Fall River. These five communities serve a total population of 42,500 people with an average of 5,630,000 gallons per day. In all cases the water is treated by rapid sand filtration and disinfection and, in some cases, it is softened and treated with activated carbon and/or prechlorination for control of tastes and odors.

All these municipalities have, at various times in the past, experienced difficulty with water supply tastes and odors. In most instances the cause was reported to have been wastes discharged into the river from one or more of the three oil refineries. However, either better handling and disposal of wastes from the Standard Oil Company of Indiana, Neodesha, and/or improved methods and procedures of water treatment, have practically eliminated the problem for all the municipalities except Nowata, Oklahoma.

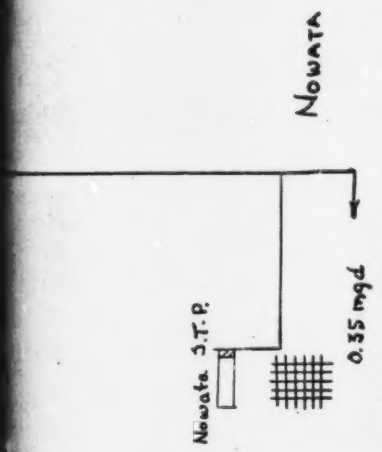
The occurrence of taste and odor problems of the Nowata water supply was discussed with the water works operator and several of the city officials. It was the general opinion that tastes and odors usually occurred during or immediately following periods of low flow. Hydrometric data show such low-flow periods occur most frequently in the late summer or fall, and frequently extend well into the winter months.

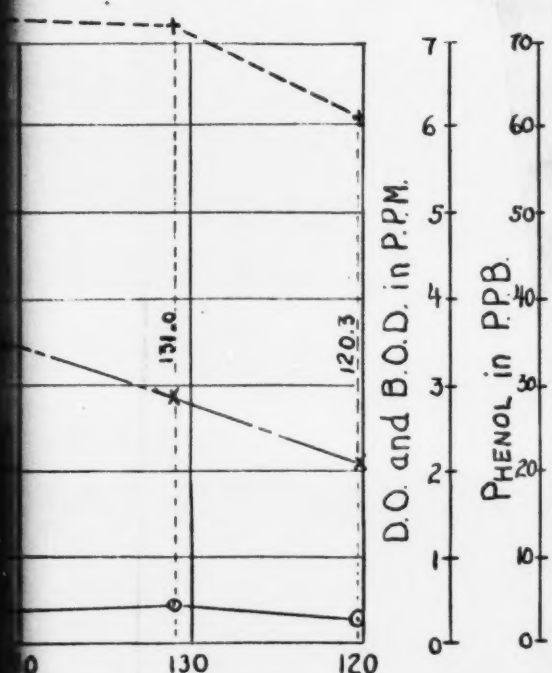

D.O. and B.O.D. in P.P.M.
0 1 2 3 4 5 6 7
PHENOL in P.P.B.
0 10 20 30 40 50 60 70
220
210
200
190
180
170
218.7
216.0
207.3
195.7
193.1
172.5
Phenol
B.O.D
D.O.
MILES ABO
FREDONIA
C.E. Gage
S.T.P
C.E. Gage
Fall River
St. Oil Co. Waste
5.0 mgd St. Oil
0.8 mgd City W.W.
S.T.P.
NEODESHA
Elk River
0.23 mgd Cherryvale W.W.
CHERRYVALE
Drum Creek
Rock Creek
Independence S.T.P.
1.75 mgd
INDEPENDENCE
U.S.G.S. Gage
2.5 mgd Coffeyville W.W.
Sinclair Ref Waste





ABOVE MOUTH OF VERDIGRIS RIVER





LEGEND

- CITY
- DAM
- MUNICIPAL OR INDUSTRIAL WATER SUPPLY.
- POPULATION EQUIVALENT OF MUNICIPAL SEWAGE.
- POPULATION EQUIVALENT OF SEWAGE OR INDUSTRIAL WASTE DISCHARGE TO RIVER.

NOTE: POPULATION EQUIVALENTS ARE BASED ON A 5-DAY B.O.D. OF 0.167 LB./CAP./DAY.

SCALE: 1" = 10,000 PEOPLE

FIGURE 1

VERDIGRIS RIVER INVESTIGATION

SOURCES OF WATER SUPPLY AND POLLUTION AND SUMMARY DATA

AUGUST 24 - OCTOBER 1, 1948

U.S. PUBLIC HEALTH SERVICE

ENVIRONMENTAL HEALTH CENTER

Table 1 - Verdigris River Investigation - Municipal and Industrial Surface Water Supplies Taken from Verdigris River and Tributaries in Reach Investigated.

Stream and municipality or industry	State	Miles above mouth	Treatment	Population served	Average consumption m. g. d.
Fall River					
Standard Oil Refinery, Neodesha	Kan.	5.7	N	-	5.0
Neodesha	"	5.6	HFD	3,500	0.80
Verdigris R.					
Cherryvale	"	203.0	FD	3,100	0.23
Independence	"	193.4	FD	14,000	1.75
Coffeyville	"	172.5	HFD	18,000	2.5
Sinclair Oil Refinery, Coffeyville	"	172.0	N	-	3.6
Co-operative Ref.Asso., Coffeyville	"	169.9	N	-	3.0
Nowata	Okla.	120.3	FD	3,905	0.35

H - Softened.
F - Coagulated, settled and filtered.
D - Chlorinated.
N - None.

Industrial Water Supplies

Table 1 shows the industrial water supplies drawn from the Verdigris and Fall rivers. The industries report a total of 11.6 million gallons per day is used for boiler, processing and cooling water. Except for boiler water, the only treatment given is occasional chlorination for algae control.

Sources of Pollution

The significant sources of pollution and the sewered population equivalent, based on a 5-day biochemical oxygen demand (5-day, 20°C.) of 0.167 pounds per capita per day, are given in Table 2. Data on the sewered population connected to sewage treatment plants have been furnished by the States and summarized by the Public Health Service in its "Inventory of Water and Sewage Facilities in the United States, 1945." Since actual test data are available for only one plant, Nowata, Oklahoma,* and cover only a short test period, secondary treatment has been assumed to provide an 85% reduction in the sewered population equivalent. Throughout most of the period of this investigation the sewage treatment plant at Coffeyville, Kansas, was being by-passed while undergoing repair; thus, no reduction for treatment has been credited.

The discharged sewered population equivalent for the three oil refineries has been computed from the average stream flow and the mean decrease in oxygen balance. Only those data for the period during which samples were collected both upstream and downstream from the refinery in question were used. Stream flows were corrected in ratio to the total tributary areas. In the vicinity of Coffeyville, corrections were made for the water drawn from and discharged into the river.

The total sewered population equivalent of the municipal and industrial wastes is 56,130 people, 18,200, or

---

* A report of tests conducted August 18-22, 1948, by engineers of the Oklahoma Division of Sanitary Engineering, shows the following:

Estimated population connected	3,750 people
Average dry weather flow	200,000 g.p.d.
Sewered population equivalent:	
Untreated sewage	2,100 people
Treated sewage	100 people

Table 2 - Verdigris River Investigation - Municipal and Industrial Sources of Pollution of Verdigris River and Tributaries in Reach Investigated.

Stream and municipality or industry	State	Miles above mouth	Population connected to sewers	Treatment (Sewage only)	Sewered population equivalent (B.O.D.)	
					Untreated	Dischgd.
Fall River						
Standard Oil Refinery, Neodesha	Kan.	5.7				1,000*
Drum Creek						
Cherryvale	"	8	2,600	Secondary	2,600	390
Verdigris R.						
Neodesha	"	216.8	2,800	Secondary	2,800	420
(Fall River)		215.3				
Independence	"	193.4	11,000	Secondary	11,000	1,650
(Drum Creek)		190.9				
Sinclair Oil Refinery, Coffeyville	"	172.0	-	-		13,000*
Co-operative Ref. Asso., Coffeyville	"	169.8	-	-		4,200*
Coffeyville	"	163.2	18,000	Secondary**	18,000	18,000**
Nowata	Okla.	124.3	3,530	Secondary	3,530	530

* Estimate based on change in oxygen balance in river.
** Coffeyville sewage treatment plant was by-passed while undergoing repair during most of the period of the investigation.

32.4 %, of which is due to wastes from the three oil refineries. Secondary sewage treatment, which is employed by all these municipapities, will reduce the sewered population equivalent, when the Coffeyville plant is again in operation, discharged into the river to 23,790 people, of which 18,200, or 76.5 %, is due to oil refinery wastes.

Phenolic Wastes

Since it has been the general opinion that phenolic wastes have been responsible for much of the trouble encountered with the taste and odor of the water supply at Nowata, Oklahoma, a special study was made of the industrial wastes from the two oil refineries at Coffeyville.

Weirs were installed on the main effluent channel of each refinery and flow measurements taken. Samples were collected and composited over several 24-hour periods and analyzed. The results are given in Table 3. Of particular interest is the daily discharge of phenol, which may be summarized as follows:

Date	Phenol discharged to river in pounds per day	
	Sinclair Oil Co.	Co-op. Ref. Asso.
9/21-22	10.3	11.1
9/23	7.3	10.2
9/28-29	12.4	16.2
9/30-10/1	8.9	16.2
Average	9.7	13.4

Additional information concerning the oil refineries and their wastes may be found in Appendix B.

Water Quality

Table 4 gives the mean result of each chemical analysis and bacteriological examination for each individual station on the Verdigris and Fall rivers. The variation throughout the course of the stream of some of the more significant data, dissolved oxygen, biochemical oxygen demand, and phenol, is shown in Figure 1. More detailed data may be found in Table 7, Appendix A.

Of particular interest are the data in the vicinity of Coffeyville, Kansas, between miles 162 and 172. High phenols and biochemical oxygen demand, also a marked petroleum odor and decreased dissolved oxygen, are found in this reach.

Table 3 - Verdigris River Investigation - Results of Analyses of Oil Refinery Wastes.

Refinery	Date and time of sampling	Flow g.p.m.	Phenol p.p.b.	B.O.D. p.p.m.	Oxygen consumed p.p.m.	Oil & grease p.p.m.
Sinclair Refining Co.	7 AM 9/21 - 6 AM 9/22	1690	510	-	-	-
	7 AM 9/23 - 12 Mdn 9/23**	1230	495	-	-	-
	7 AM 9/28 - 6 AM 9/29	1520	650	32	-	-
	7 AM 9/30 - 6 AM 10/1	1360	535	57	37	39
Cooperative Refinery Association	7 AM 9/21 - 6 AM 9/22	695	1330	-	-	-
	7 AM 9/23 - 6 AM 9/24	700*	1220	-	-	-
	7 AM 9/28 - 6 AM 9/29	845	1600	39	-	-
	7 AM 9/30 - 6 AM 10/1	840	1610	34	28	17

* Flow measurement estimated for first 12-hour period due to trouble with leakage under weir.

** Sampling not continued over 24-hour period due to breakdown of car.

Table 4 - Verdigris River Investigation - Summary of Analytical Results of Sampling - August 24 - October 1, 1948

Miles above mouth	Number of samples	Temp. av'g. in °C	pH av'g.	Chlorides	Chlorine demand	Phenol av'g.	D.O.	B.O.D.	Odor		Coliform bacteria median count per 100 ml
				Average in parts per million		p.p.b.	Average in p.p.m.		Median dilution	Predominant description	
Fall River											
8.2	6	21.7	7.9	102	-	4	6.4	0.9	-	-	-
5.7	Standard Oil Co. Refinery, Neodesha										
5.6	14	25.5	7.7	118	0.6	11	5.6	2.2	3	Earthy	60
Verdigris River											
218.7	14	23.4	8.0	123	0.7	5	6.4	1.5	2	Earthy	150
216.8	Neodesha Sewage Treatment Plant										
216	9	23.4	7.9	-	-	-	7.0	1.5	-	-	-
215.3	Fall River										
207.3	14	23.6	7.9	124	1.1	4	6.8	2.2	2	Earthy	11,000
197.8	Elk River										
195.7	14	24.7	8.0	123	0.6	5	6.5	1.7	2	Earthy	240
193.4	Independence Sewage Plant Effluent Enters Through Rock Creek										
193.1	10	24.3	7.9	133	-	4	6.3	1.6	-	-	-
172.5	14	25.3	7.9	95	0.6	6	6.8	2.3	2	Earthy	93
172.0	Sinclair Oil Co. Refinery, Coffeyville										
171.3	14	25.5	8.0	98	0.7	21	5.2	4.8	4	Petroleum	930
169.9	Cooperative Refinery Association Plant										
169.7	5	24.1	7.9	100	0.5	60	4.5	6.4	4	Petroleum	-
167.1	14	24.9	7.9	100	0.5	9	6.1	3.9	3	Petroleum, earthy and musty	195
163.2	Coffeyville Sewage Treatment Plant										
162.5	8	24.7	7.8	109	-	-	5.4	4.6	-	-	-
159.4	7	25.4	7.8	102	0.4	6	5.3	4.9	3	Earthy	4,600
144.6	14	24.4	8.1	97	0.6	4	7.3	3.8	3	Earthy	430
131	7	25.9	8.0	86	0.6	5	7.2	2.9	2	Earthy	240
124.3	Nowata Sewage Treatment Plant Effluent Enters Through Ditch										
120.3	14	24.8	7.8	116	0.5	3	6.1	2.1	2	Earthy	150

Hydrometric Data

Records of the discharges of the Verdigris and Fall rivers of interest in connection with this report are available for four stations, from the dates indicated to the present:

Station	Date of first record
Verdigris R. near Altoona, Kans.	November, 1938
Verdigris R. at Independence, Kans.	November, 1921
Verdigris R. near Lenapah, Okla.	April, 1939
Fall R. at Fredonia, Kans.	November, 1938

Table 5 gives the daily discharge for each of these stations for the period immediately preceding and during this investigation. This information has been provided through the co-operation of the Corps of Engineers and the U.S.Geological Survey.

Table 8, Appendix A, gives the mean monthly discharge of the Verdigris River at Independence, Kansas, as published in the Water Supply Papers of the U.S.Geological Survey. These data have been used to plot the Low-Flow Frequency Curve, Figure 2, which shows the expectancy of low monthly flows by water years. Examination of this curve shows that the average flow for the month of minimum flow may be expected to be equal to or less than 26 c.f.s. one year out of two; equal to or less than 6 c.f.s. one year out of four; and equal to or less than 0.8 c.f.s. one year in ten.

For purposes of comparison, it should be noted that the average flow of the Verdigris River at Independence was 468 c.f.s. during the month of August, and 73 c.f.s. during September, 1948.

The time of flow, as estimated from discharge and the area of various stream sections, for that reach between Coffeyville, Kansas, and the intake of the Nowata, Oklahoma, water works, is as follows:

Verdigris River Discharge (c.f.s.)	Velocity of Flow, (mi./day)	Time of Flow, Coffeyville to Nowata (Days)
0	0	----
10	1.6	28.4
25	3.3	13.8
50	5.4	8.4
100	9.2	5.0

FIGURE 2

LOW FLOW FREQUENCY CURVE

VERDIGRIS RIVER AT INDEPENDENCE, KANSAS

NOTE: CURVE PLOTTED FROM DATA FOR WATER YEARS 1921-22 THROUGH 1942-43 AS OBTAINED FROM U.S.G.S. WATER SUPPLY PAPERS.

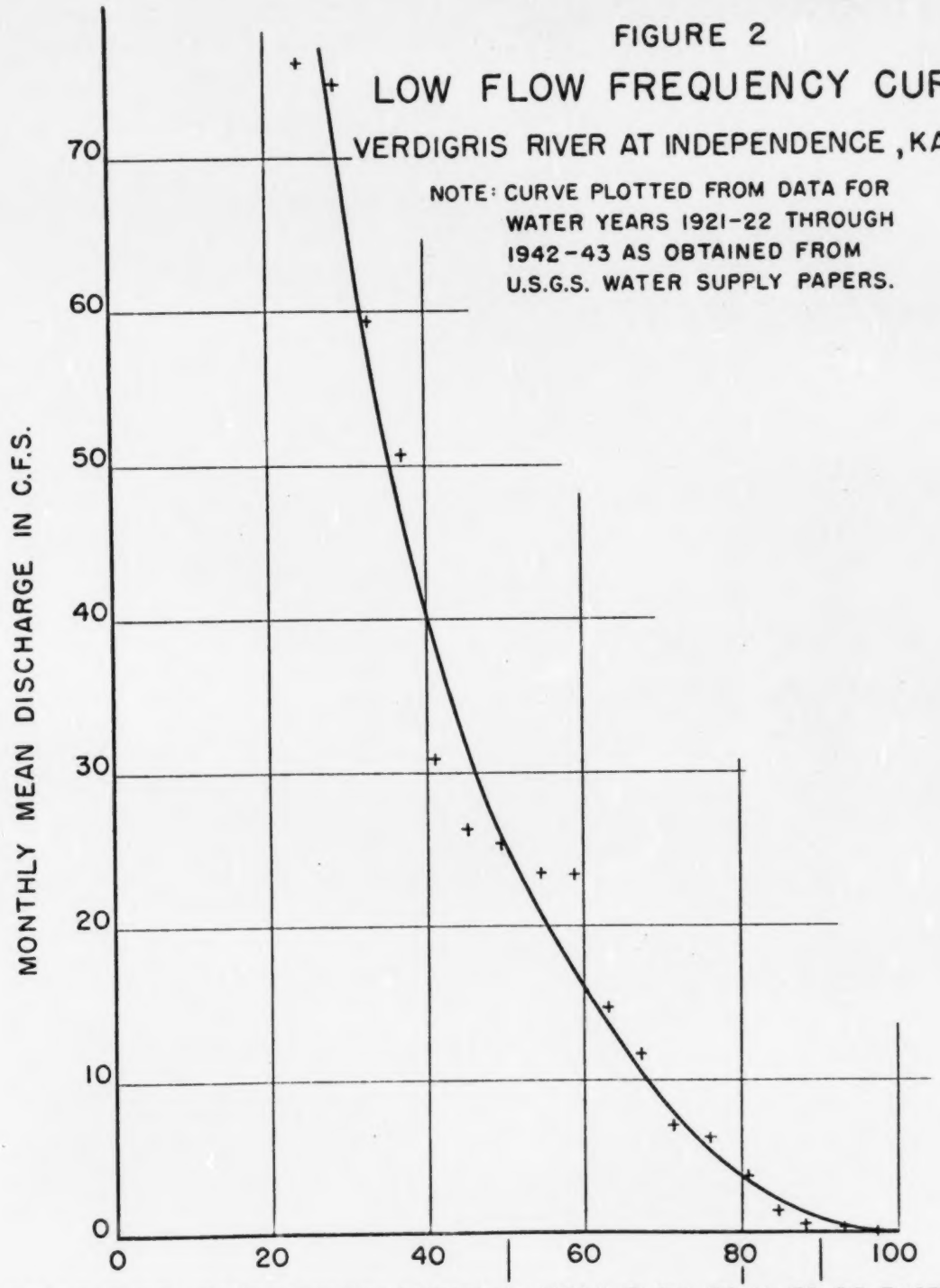


Table 5 - Verdigris R. Investigation - Daily River Discharge in Cubic Feet per Second

Day of Month	Fall River near Fredonia, Kansas D.A. = 816 sq.mi.		Verdigris River Near Altoona, Kans. D.A. = 1150 sq.mi.		Verdigris River At Independence, Kans. D.A. = 2892 sq.mi.			Verdigris River Near Lenapha, Okla. D.A. = 3625 sq.mi.	
	August	September	August	September	July	August	September	August	September
1	559	36	318	42	2,460	865	116	1,450	161
2	523	34	261	42	1,200	708	108	989	143
3	490	31	226	40	848	655	100	809	133
4	424	29	194	35	655	708	92	782	123
5	374	28	167	32	520	505	92	756	116
6	325	27	141	32	445	445	93	594	110
7	280	26	130	30	388	402	93	533	106
8	250	25	123	32	343	368	93	680	103
9	235	24	118	31	289	416	94	495	98
10	200	24	123	42	1,760	520	94	594	96
11	160	23	116	103	6,400	445	95	615	96
12	130	23	112	75	12,800	690	95	11,000	96
13	112	22	112	61	14,600	672	96	5,000	102
14	110	22	110	47	8,950	778	96	5,040	125
15	157	21	105	36	11,100	935	88	2,690	114
16	143	21	167	30	18,300	1,000	80	3,750	103
17	129	20	150	27	22,400	520	72	1,490	94
18	114	20	226	25	28,200	620	67	809	86
19	102	19	153	22	34,600	568	62	837	80
20	93	19	112	20	37,700	416	59	659	75
21	89	18	103	18	36,400	325	52	495	73
22	84	18	136	17	36,400	279	49	400	70
23	78	17	110	18	48,000	260	47	357	64
24	69	17	87	17	41,400	240	44	333	58
25	57	16	74	15	26,000	220	41	287	54
26	50	16	64	13	7,750	200	37	271	49
27	44	16	62	15	3,690	180	35	336	47
28	46	15	61	15	1,710	160	34	228	45
29	43	15	59	13	1,360	140	32	212	43
30	43	15	52	16	2,200	132	33	202	41
31	39	--	47	--	1,360	124	--	180	--
Avg.	179	21.9	130	32	13,233	468	73	1,383	90.1
Max.	559	36	318	103	48,000	1,000	116	11,000	161
Min.	39	15	47	13	289	124	32	180	41

Discussion

Results of the chemical analyses and bacteriological examinations show only slight, local pollution of the Verdigris River upstream from Coffeyville, Kansas. The most critical reach of the river occurs in the vicinity of and immediately downstream from that city. Here increased pollution results from industrial wastes; the mean values for dissolved oxygen fall from 6.8 to 4.5 p.p.m., mean biochemical oxygen demand results increase from 2.3 to 6.1 p.p.m., and phenol results increase from 6 to 60 p.p.b. Stream recovery, however, is rapid, even though a temporary setback occurs due to the entrance of domestic sewage and miscellaneous industrial wastes from Coffeyville. Under conditions occurring during this investigation, the stream had greatly recovered prior to its reaching the Nowata, Oklahoma, water plant intake. A comparison of the quality of the raw water as taken from the Fall and Verdigris rivers by the several municipalities is given in Table 6.

During the period of the investigation, August 24 through October 1, 1948, the daily discharge of the Verdigris River at Independence, Kansas, gradually fell from 240 to 33 c.f.s. The average for the month of September was 73 c.f.s. Such a favorable flow for the minimum monthly discharge will occur in only one out of three years. Moreover, recent floods, one in the spring and a second during the latter part of July, undoubtedly flushed the river channel. Stream flow conditions immediately preceding and during the investigation were unfavorable toward the development of the normal annual pollutional problem in this reach of the Verdigris River.

Although the results of this investigation, and the absence of any taste or odor problem in the Nowata, Oklahoma, water supply, are evidences that the natural stream processes and dilution provided sufficient natural purification to prevent a taste and odor problem at Nowata, such a taste and odor problem may occur under less favorable conditions.

The combined wastes discharged from the two refineries at Coffeyville contained an average of 23.1 pounds of phenol per day. With this load, the initial concentrations which would result in the Verdigris River at various flows are:

Table 6 - Verdigris River Investigation - Comparison of Raw Water Quality - Number of Samples Falling in Various Ranges and Most Critical Determination.*

Phenols parts per billion

	0-1	2-10	>11	Max
Mowata	7	5	1	14
Neodesha	5	6	3	81
Independence	9	4	1	43
Coffeyville	2	8	2	17

D. O. parts per million

	0-3	>3-5	>5	Min
Mowata	2	1	11	2.9
Neodesha	1	4	9	2.6
Independence	0	0	14	5.3
Coffeyville	0	1	13	3.6

B. O. D. parts per million

	0-3	>3-5	>5	Max
Mowata	11	2	1	8.4
Neodesha	11	1	2	6.3
Independence	12	2	0	4.7
Coffeyville	10	3	1	7.5

Coliform bacteria Count per 100 ml.

	0-500	501-5000	5001-10,000	Max
Mowata	14	0	0	390
Neodesha	12	0	0	240
Independence	13	0	0	460
Coffeyville	13	1	0	930

Chlorides parts per million

	0-100	101-250	>250	Max
Mowata	4	10	0	155
Neodesha	1	13	0	145
Independence	2	12	0	160
Coffeyville	12	2	0	105

Chlorine demand parts per million

	0-0.5	>0.5-1.0	>1.0	Max
Mowata	8	5	0	0.9
Neodesha	6	6	1	>1.0
Independence	7	5	2	1.1
Coffeyville	5	8	0	1.0

* Maximum or minimum concentration for constituent.

Stream discharge c.f.s.	Phenol concentration p/p.b.	Remarks
400	10	
300	14	
200	21	
100	43	
73	59	Average flow during September, 1948
26	165	Minimum monthly mean flow expected once in 2 years
6	715	Minimum monthly mean flow expected once in 4 years
0.8	5,350	Minimum monthly mean flow expected once in 10 years

The persistence of phenol and cresols in natural waters was investigated by Ettinger and Ruchhoft.* At 20°C it was found that in two days phenol and cresol were removed from natural waters which had a previous history of phenol pollution and were seeded with phenol-oxidizing organisms. In such a case the stream flow would have to exceed 400 c.f.s. for phenol to persist in the water as far downstream as Nowata. At such a flow, dilution would reduce the phenol concentration in the river to 10 p.p.b. and biological oxidation would cause further reduction. There should be no difficulty with taste and odor problems of the Nowata water when the temperature of the water is in the neighborhood of, or above, 20°C.

At low water temperatures (around 4°C.) the above-mentioned authors found phenol and cresols to persist in natural waters, such as the Verdigris River, for 6 days. This indicates that whenever the flow exceeds 75 c.f.s. there is insufficient elapsed time for biological oxidation of the phenol in the water prior to its arrival at Nowata. Estimates of the effect of dilution and time of flow show the phenol concentrations in the water at Nowata would become a maximum of about 12 p.p.b. with a steady flow of 200 to 300 c.f.s.

It is believed, however, that a maximum concentration of phenol (approximately 40 to 50 p.p.b.) may occur as the result of the following:

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* Ettinger, M.B., and Ruchhoft, C.C. The Removal of Phenols and Cresols in Natural Waters. (In press, Journal of Industrial and Chemical Engineering).

(1) Low water temperature.
(2) A period of low flow (10 c.f.s. or less).
(3) A rapid rise in the river to move the phenol-laden water downstream.

During periods of both low flow and low water temperatures, the accumulated phenol in the reach of stream extending a few miles downstream from the refinery may reach 70 to 100 pounds, with the average phenol concentration in the water being several hundred parts per billion. With a rising stream flow, this slug of phenol-laden water may be flushed rapidly downstream and could result in phenol concentrations in the Nowata water of 40 to 50 p.p.b.

The above discussion assumes the wastes discharged to the river by the two Coffeyville refineries contain 23.1 pounds of phenol each day, which is the average loading as determined during this investigation. The discharge of waste from either refinery containing unusual amounts of phenol, such as might result from spills, failure to impound the stronger phenolic wastes, or by-passing treatment units, would obviously increase the phenol concentration in the water at Nowata, especially during periods of low water temperature.

APPENDIX A

Table 7 - Results of Analyses of Samples.

Table 8 - Mean Monthly Flow of Verdigris River at Independence, Kansas.

Table 7 - Verdigris River Investigation - Results of Analyses of Samples
(Sheet 1 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor		Coliform bacteria per 100 ml.	Remarks
								Dilution	Description		
Fall River (Mile 8.2) at County Highway Bridge (SW 1/4, Section 13) NW of Neodesha											
9/15	23	8.0	105	-	4	6.5	0.9	3	Musty	240	
9/17	22	8.0	105	-	6	6.6	1.2	-	-	-	
9/21	24	7.9	100	-	0	5.5	0.6	-	-	-	
9/23	23½	7.9	105	-	8	5.5	0.4	-	-	-	
9/27	19½	7.9	100	-	0	7.0	1.2	-	-	-	
9/29	18	7.7	99	-	5	7.0	0.9	-	-	-	
Avg.	21.7	7.9	102	-	4	6.4	0.9	-	-	-	
Fall River (Mile 5.6) at U.S. Highway No. 75 Bridge West of Neodesha											
8/25	28	7.6	94	0.6	4	6.8	0.9	2	Earthy	-	
8/27	28	7.8	110	0.4	1	6.2	5.4	3	Earthy	91	
8/31	28	7.9	140	-	8	7.0	6.3	4	Sewage	150	
9/2	27½	7.7	145	0.4	1	4.6	1.5	3	Earthy	43	
9/7	26½	7.9	140	0.9	1	5.7	0.8	3	Musty	43	
9/9	25	7.7	130	0.8	11	5.8	2.3	3	Earthy	75	Oil scum
9/13	23	7.6	120	0.8	26	6.2	1.4	3	Musty	45	
9/15	24	7.8	115	1.0	0	4.6	1.3	3	Musty	15	
9/17	24	8.0	110	0.4	7	7.5	1.2	2	Earthy	240	Oil streaks
9/21	24½	7.9	110	0.7	2	4.7	1.4	2	Musty	15	Oil streaks
9/23	26	7.8	110	0.3	1	5.6	1.1	3	Earthy	43	
9/27	24	7.7	110	0.5	2	2.6	1.0	3	Sewage	240	
9/29	25	7.9	110	0.3	6	5.1	2.3	2	Earthy	-	
9/30	23	7.5	110	0.6	81	3.6	3.6	2	Earthy	150	
Avg.	25.5	7.7	118	0.6	11	5.6	2.2	3*	Earthy**	60*	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 2 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor		Coliform bacteria per 100 ml.	Remarks
								Dilution	Description		
Verdigris River (Mile 218.7) at U.S. Highway No. 75 Bridge East of Neodesha											
8/25	28½	7.4	85	0.3	7	6.0	1.4	1	Earthy	360	
8/27	26½	7.9	66	0.7	2	5.9	6.2	2	Earthy	1500	
8/31	27½	8.0	89	0.4	10	5.9	3.3	2	Earthy	930	
9/2	26½	8.1	88	0.9	0	6.2	1.2	3	Earthy	240	
9/7	26	8.3	99	0.9	9	7.2	1.0	2	Earthy	110	
9/9	22	8.0	105	1.4	5	6.2	1.6	3	Earthy	150	
9/13	21	7.8	200	0.9	1	6.9	0.8	2	Musty	150	
9/15	24	8.2	275	1.0	0	7.9	1.2	3	Musty	240	
9/17	23½	8.0	170	0.5	10	7.2	1.3	1	Earthy	93	
9/21	25	7.9	99	0.9	0	5.4	0.8	1	Musty	43	
9/23	24	7.7	125	0.5	10	5.1	0.5	2	Earthy	43	
9/27	18	8.0	110	0.5	4	6.3	0.9	1	Earthy	240	
9/29	17	8.0	110	0.7	6	6.8	0.6	0	Earthy	75	
9/30	18	8.2	105	0.7	6	7.0	0.7	1	Earthy	43	
Avg.	23.4	8.0	123	0.7	5	6.4	1.5	2*	Earthy**	150	
Verdigris River (Mile 216.) 0.9 Miles Below Outfall Neodesha Sewage Treatment Plant											
9/2	26	-	-	-	-	5.7	1.6	-	-	-	
9/7	26½	-	-	-	-	8.0	0.3	-	-	-	
9/9	22	-	-	-	-	6.1	2.0	-	-	-	
9/13	22	7.8	-	-	-	7.9	1.2	-	-	-	
9/15	24	8.0	235	-	0	8.5	1.6	-	-	-	Oil streaks from pipe line leakage about 100' downstream.
9/17	23½	8.0	190	-	7	7.3	1.7	-	-	-	
9/21	25	-	140	-	0	6.3	1.9	-	-	-	Oil streaks
9/23	23½	7.7	130	-	-	5.7	1.6	-	-	-	
9/29	18	8.2	-	-	-	7.9	1.9	-	-	-	
Avg.	23.4	7.9	174	-	-	7.0	1.5	-	-	-	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 3 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor		Coliform bact.per 100 ml.	Remarks
								Dilution	Description		
Verdigris River (Mile 207.3) at County Highway 1½ Miles East of Sycamore											
8/25	28	8.4	97	0.6	3	6.6	1.1	3	Earthy	9,300	Oil streaks
8/27	26½	7.8	105	5.0	2	5.6	5.6	3	"	11,000	
8/31	27½	7.7	125	0.9	9	5.4	6.8	3	"	11,000	
9/2	26½	7.7	115	0.9	1	5.8	1.0	2	"	11,000	Oil streaks
9/7	26	8.2	115	1.4	6	6.1	1.0	2	"	11,000	
9/9	22	7.8	115	1.4	5	6.6	2.4	3	"	24,000	Oil scum
9/13	21½	7.8	165	0.4	6	6.7	1.4	3	"	9,300	Oil scum
9/15	23½	8.0	180	1.0	0	6.9	1.4	2	"	9,300	Considerable oil scum
9/17	24	7.9	165	0.5	9	7.5	2.7	1	"	9,300	
9/21	25½	7.9	100	0.5	0	6.3	1.7	2	Musty	24,000	Oil streaks
9/23	24½	7.8	125	0.5	3	6.2	1.4	3	Earthy	4,300	Oil streaks
9/27	19	7.9	110	0.5	0	7.9	1.2	2	"	110,000	
9/29	19	7.8	110	0.7	7	8.9	1.5	1	"	11,000	
9/30	18½	7.8	110	0.7	0	8.5	1.2	1	"	24,000	
Avg.	23.6	7.9	124	1.1	4	6.8	2.2	2*	Earthy**	*11,000	
Verdigris R.(Mile 195.7)at Old Boat Dock About 1/4 mi.upstream fr.Independence Water Works											
8/25	29	8.4	90	0.6	5	8.4	2.2	3	Earthy	-	
8/27	27½	7.9	115	1.1	0	6.3	4.7	3	"	430	
8/31	28	7.8	91	0.4	8	6.2	4.1	3	"	460	
9/2	27½	7.8	120	0.4	0	6.1	2.3	2	"	460	
9/7	27	8.1	100	0.4	0	6.2	0.9	3	"	240	
9/9	22½	7.7	100	0.9	1	5.6	1.8	2	"	240	
9/13	23	7.8	145	0.4	1	6.9	1.0	3	"	120	
9/15	23	8.2	110	1.0	0	7.5	1.1	3	"	75	
9/17	24	7.9	115	0.5	9	7.6	1.3	2		93	
9/21	25	8.3	125	0.7	0	7.4	0.8	2	Musty	430	
9/23	24½	7.9	145	0.7	1	6.3	0.8	2	Earthy	430	
9/27	-	7.7	155	0.5	0	5.4	1.1	3	Petroleum	64	
9/29	20	7.9	160	0.5	6	5.3	0.8	1	Earthy	91	
9/30	20	7.9	155	0.7	43	6.4	0.9	1	"	150	
Avg.	24.7	8.0	123	0.6	5	6.5	1.7	2*	Earthy**	*240	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 4 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor		Coliform bact.per 100 ml.	Remarks
								Dilution	Description		
Verdigris River (Mile 193.1) about 1/3 mile below Mouth of Rock Creek - Effluent from Indopendenco Sewage Treatment Plant											
9/2	27½	-	-	-	-	5.9	2.6	-	-	-	
9/7	26½	-	-	-	-	5.8	0.7	-	-	-	
9/9	23½	-	-	-	-	5.9	1.9	-	-	-	
9/13	23	7.9	-	-	-	7.2	1.7	-	-	-	
9/15	23½	8.2	115	-	0	6.6	1.9	-	-	-	
9/17	24½	7.9	92	-	10	6.7	0.2	-	-	-	
9/21	26	-	125	-	1	6.4	1.3	-	-	-	
9/23	24½	8.0	135	-	10	6.3	1.7	-	-	-	Yellow patches of foam
9/27	-	7.8	160	-	0	6.3	2.3	-	-	-	Oil slick
9/29	20	7.9	170	-	5	5.7	2.2	-	-	-	
Avg.	24.3	7.9	133	-	4	6.3	1.6	-	-	-	
Verdigris River (Mile 172.5) at Coffeyville Water Works Pumping Plant											
8/25	30	8.4	78	0.6	2	10.0	3.9	2	Sewage	300	
8/27	28	7.8	87	1.0	2	7.7	3.3	4	Earthy	930	
8/31	28	7.7	87	0.4	9	6.9	7.5	2	"	150	
9/2	28½	7.7	97	0.4	9	6.5	3.6	2	"	240	Sample taken from shore upstream due to work on intake.
9/7	27½	7.8	97	0.8	17	6.8	1.3	3	"	230	
9/9	25½	7.7	105	0.9	9	6.5	2.4	2	"	93	
9/13	25	7.8	94	0.4	6	6.7	1.1	2	Musty	93	
9/16	24½	7.9	91	0.4	10	6.2	1.3	2	Earthy	150	
9/20	25½	7.9	90	0.7	0	7.4	1.8	3	Fishy	93	Returned to sampling from boat.
9/22	24½	8.3	100	0.5	0	3.6	1.0	2	Earthy	43	
9/24	24	8.0	97	0.7	3	6.4	1.4	3	Petroleum	43	
9/28	21½	8.1	100	0.7	2	6.4	1.1	1	Earthy	23	
9/30	21	7.9	105	0.7	-	7.3	1.4	1	"	23	
10/1	20½	8.1	100	-	-	7.0	1.2	2	"	93	
Avg.	25.3	7.9	95	0.6	5	6.8	2.3	2*	Earthy**	93*	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 5 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor		Coliform bact. per 100 ml.	Remarks
								Dilution	Description		
Verdigris River (Mile 171.3) on Britten Farm Below Sinclair Refinery Outfall											
8/26	28½	8.2	81	0.5	14	6.4	3.4	4	Petroleum	930	Oil streaks
8/30	29½	7.9	87	1.9	0	8.5	11.6	4	"	240	
9/1	28	8.0	91	0.9	15	5.6	3.5	3	"	240	
9/3	27	7.7	105	1.9	14	5.4	4.3	4	"	460	Oil patches
9/8	27	7.7	110	0.4	20	5.5	4.6	5	"	230	Oil scum
9/10	24	7.9	105	0.4	24	4.8	3.6	4	"	1,100	Oil scum
9/14	24½	7.9	94	0.4	25	5.7	3.0	3	"	930	Oil streaks
9/16	24½	7.9	97	0.4	22	4.8	4.5	3	"	240	Oil scum
9/20	25½	7.8	95	0.3	26	4.6	3.8	4	"	2,400	
9/22	25	8.1	96	0.3	26	7.5	7.3	3	"	-	Some oil
9/24	24½	8.3	100	0.5	8	4.4	3.3	4	"	1,100	
9/28	21½	8.4	105	0.5	25	4.5	3.3	3	"	1,100	
9/30	-	8.2	105	0.7	55	1.4	3.4	2	"	2,400	
10/1	22	8.3	105	-	-	4.2	8.3	4	"	11,000	
Avg.	25.5	8.0	98	0.7	21	5.2	4.8	4*	Petroleum**	930*	
Verdigris River at U.S. Highway No. 169 Bridge (Mile 169.7) NE of Coffeyville, 0.2± Mile below Coop Refinery Outfall											
9/16	25	7.9	105	0.4	26	5.9	4.0	4	Petroleum	240	Heavy black oil covering R
9/20	26	8.0	96	0.6	129	5.7	5.5	3	"	93	Oil streaks
9/22	25	7.9	96	-	33	2.9	13.9	4	"	-	
9/24	23½	7.7	98	-	43	3.1	3.1	4	"	-	Heavy oil scum
9/28	21	8.0	105	0.5	70	4.8	5.6	5	"	-	Heavy oil slick
Avg.	24.1	7.9	100	0.5	60	4.5	6.4	4*	Petroleum**	-	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 6 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor Dilution	Odor Description	Coliform bact.per 100 ml.	Remarks
Verdigris River (Mile 167.1) at U. S. Highway No. 166 Bridge East of Coffeyville											
8/26	27½	8.1	79	0.5	-	5.8	2.6	4	Petroleum	36	
8/30	30	8.3	86	0.9	4	6.7	12.5	3	Musty	460	
9/1	27½	7.8	91	0.9	4	5.2	5.2	3	Petroleum	11,000	
9/3	26½	7.7	97	0.9	5	4.6	2.6	2	Sewage	460	
9/8	25½	7.7	110	0.9	6	5.4	2.2	3	Petroleum	430	
9/10	22½	7.8	105	0.4	6	5.2	2.4	3	Musty	36	Oil streaks
9/14	24½	7.9	100	0.4	5	5.0	2.4	3	Cassy	1,100	Oil streaks
9/16	24½	7.9	100	0.2	12	4.9	2.6	3	Earthy	240	Few oil spots
9/20	26	7.9	99	0.3	11	5.5	3.4	2	Musty	23	
9/22	25	7.7	100	0.3	20	2.9	4.4	3	Sour	93	Spots of oil
9/24	24	7.7	100	0.3	8	4.4	4.4	3	Petroleum	240	
9/28	20	8.0	110	0.3	1	8.3	3.3	4	"	93	
9/30	-	8.0	110	0.7	25	10.6	3.5	3	Earthy	150	
10/1	20	8.2	110	-	15	10.7	3.0	2	"	150	
Avg.	24.9	7.9	100	0.5	9	6.1	3.9	3*	Pet.,Earthy & Musty**	*195	
Verdigris River (Mile 162.5) at County Highway Bridge 3/4 Mile Below Coffeyville Sewage Treatment Plant											
9/3	27½	-	-	-	-	5.2	4.4	-	-	-	
9/8	25½	-	-	-	-	4.4	4.6	-	-	-	
9/10	22½	-	-	-	-	3.7	5.7	-	-	-	
9/14	24	8.2	110	-	1	8.0	5.4	-	-	-	
9/16	25½	8.1	105	-	10	8.9	4.6	-	-	-	Some oil
9/20	26	7.7	110	-	0	7.6	5.4	-	-	-	heavy oil film
9/22	26½	7.5	110	-	-	3.7	3.7	-	-	-	Oil slick
10/1	20	7.5	-	-	-	1.5	3.3	-	-	-	Light oil slick
Avg.	24.7	7.8	109	-	-	5.4	4.6	-	-	-	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 7 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor Dilution	Odor Description	Coliform bact.per 100 ml.	Remarks
Verdigris River (Mile 159.4) at County Highway Bridge SE of South Coffeyville											
8/30	-	7.8	90	0.8	2	6.6	11.9	3	Earthy	11,000	
9/1	27½	7.8	91	0.4	2	4.7	4.5	3	"	15,000	
9/3	26½	7.7	94	0.4	0	4.6	3.2	3	"	24,000	
9/8	26½	7.8	115	0.4	10	5.6	3.0	4	"	2,400	
9/10	23½	7.8	110	0.4	7	4.9	3.4	3	Musty	4,600	
9/14	24	8.0	115	0.3	7	6.1	4.5	2	Earthy	4,600	
9/16	24½	7.9	100	0.2	12	4.9	2.6	3	"	240	
Avg.	25.4	7.8	102	0.4	6	5.3	4.9	3*	Earthy**	*4,600	
Verdigris River (Mile 144.6) at County Highway Bridge 2-3/4 Miles East of Lenapah											
8/26	-	8.2	69	0.4	4	7.0	2.4	3	Earthy	230	
8/30	28½	7.9	78	0.9	3	7.5	11.6	3	Musty	4,600	
9/1	28	7.9	83	0.4	6	7.3	4.2	3	Earthy	460	
9/3	27½	7.9	88	0.4	4	6.2	2.7	3	"	11,000	
9/8	25½	7.9	97	0.4	5	6.9	2.6	3	"	91	
9/10	23½	8.0	98	0.9	5	6.8	2.2	2	"	93	
9/14	23½	8.4	105	0.6	2	7.0	2.1	1	"	150	
9/16	24	8.2	95	0.4	11	7.2	3.2	3	Resinous	21	
9/20	25	7.7	115	0.5	0	6.2	5.1	3	Earthy	2,400	
9/22	24½	8.0	110	0.7	0	6.1	2.3	2	Musty	240	
9/24	24½	8.5	110	0.9	6	10.9	5.6	2	Earthy	930	
9/28	19½	8.1	105	0.7	1	8.0	3.7	2	"	930	
9/30	-	8.0	105	0.5	0	7.8	2.5	2	"	430	
10/1	19	8.2	105	-	-	7.4	2.9	3	Sewage	-	
Avg.	24.4	8.1	97	0.6	4	7.3	3.8	3*	Earthy**	*430	

* Median value.

** Predominant odor.

Table 7 (Cont'd.) (Sheet 8 of 8)

Date 1948	Temp °C.	pH	Chlorides ppm	Chlorine demand p.p.m.	Phenol p.p.b.	D.O. ppm	BOD ppm	Odor Dilution	Odor Description	Coliform bact. per 100 ml.	Remarks
Verdigris River (Mile 131) at Oklahoma State Highway No. 28 Bridge SE. of Delaware											
8/26	-	8.2	71	0.5	4	7.8	2.1	1	Earthy	230	
8/30	28½	7.9	76	0.9	0	7.7	8.4	3	Musty	2,400	Oil streaks
9/1	27	7.9	78	0.9	5	7.0	3.5	2	Earthy	460	Oil slick
9/3	27	7.9	82	0.4	4	6.2	2.0	2	"	460	
9/8	27	7.7	92	0.4	9	7.0	1.2	3	"	240	
9/10	22½	8.0	110	0.4	6	7.2	1.6	2	"	140	
9/14	23½	8.3	96	0.4	7	7.8	1.7	1	"	23	
Avg.	25.9	8.0	86	0.6	5	7.2	2.9	2 *	Earthy **	240	
Verdigris River (Mile 120.4) from Raw Water Well, Nowata Water Works											
8/26	-	7.4	82	0.4	0	3.0	3.0	2	Earthy	150	8/27 Nowata STP Pri.Tr.only as result of rainfall.
8/30	28	7.7	74	0.9	8	6.5	8.4	2	Musty	390	
9/1	27½	7.7	83	0.9	1	6.1	3.2	3	Earthy	150	Visible oil film
9/3	27	7.7	97	0.4	0	5.7	1.9	2	"	93	
9/8	26½	7.7	115	0.4	4	4.7	2.1	2	"	240	Oil film, Nowata STP bypassed
9/10	22½	7.7	115	0.4	8	2.9	2.1	2	"	93	9/9 & 9/10, oil slick, primary treatment only.
9/14	24	8.3	115	0.6	0	7.4	0.9	2	"	150	
9/16	25	8.1	115	0.3	14	6.5	1.1	2	Resinous	93	
9/20	26½	7.7	115	0.3	0	5.0	1.1	2	Earthy	240	
9/22	25	7.8	130	0.7	0	6.4	0.7	1	"	93	
9/24	26	7.9	135	0.5	5	7.3	1.4	2	"	93	
9/28	20½	7.9	150	0.5	3	7.3	1.1	2	"	240	
9/30	-	7.7	155	0.7	0	7.8	1.1	1	"	75	
10/1	19½	7.9	140	-	-	[illegible]	0.9	1	Musty	240	Light oil slick
Avg.	24.8	7.8	116	0.5	3	6.1	2.1	2 *	Earthy **	150	
Verdigris River (Mile 120.5) at U.S. Highway No. 60 Bridge East of Nowata											
9/26	20½	7.9	150	0.5	3	7.8	1.0	1	Earthy	150	Oil film along banks
10/1	19½	7.9	140	-	-	8.2	0.9	1	Musty	240	Light oil slick

* Median value.

** Predominant odor

Table 8 - Verdigris River Investigation - Mean Monthly Flow of Verdigris River at Independence, Kansas, in Cubic Feet per Second

Month	Water Year 1921-1922	1922-1923	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
October		23.4	1,870	834	38.4	8,140	10,300
November		119	888	1,430	2,450	395	338
December	11.8	45.6	1,430	356	165	671	599
January	13.0	37.2	283	1,470	383	725	497
February	29.3	39.7	1,170	747	256	747	1,420
March	2,800	361	2,850	286	258	1,490	2,310
April	11,500	304	1,550	1,820	2,850	19,500	1,770
May	4,310	2,150	1,810	983	431	1,110	612
June	651	10,300	1,400	298	578	6,230	9,340
July	6,920	516	800	59.4	25.2	460	875
August	235	33.2	2,170	61.5	68.2	4,770	275
September	93.4	317	1,260	567	3,980	879	142

	1928-1929	1929-1930	1930-1931	1931-1932	1932-1933	1933-1934	1934-1935
October	110	47.7	70.3	14.8	16.5	40.3	354
November	6,920	137	546	4,980	3.6	53.3	1,379
December	2,740	68.4	578	875	48.1	435	202
January	3,490	45.0	197	1,090	28.5	187	674
February	536	633	366	1,030	16.1	57.6	445
March	1,080	78.1	888	494	148	114	350
April	9,060	586	1,270	528	962	981	664
May	8,760	4,410	2,630	395	1,820	1,750	10,930
June	3,220	2,040	2,900	2,900	55.4	215	13,800
July	2,240	99.2	514	670	117	11.8	444
August	212	23.1	30.9	38.4	785	1.4	110
September	50.6	875	107	21.3	462	229	74.8

Table 8 (Cont'd.)

Month	Water Year 1935-1936	1936-1937	1937-1938	1938-1939	1939-1940	1940-1941	1941-1942
October	274	2,237	9.8	18.3	0	6.1	8,439
November	3,959	248	7.0	21.6	0	586	4,246
December	740	299	17.5	17.9	0	339	1,210
January	478	613	22.9	20.4	0	2,755	516
February	143	748	86.3	14.2	0	1,761	2,111
March	121	1,152	1,164	40.1	9.3	401	1,380
April	42.9	1,572	1,626	665	1,341	4,781	6,089
May	524	1,225	10,030	1,074	1,095	573	1,659
June	129	3,841	5,302	608	292	6,398	5,705
July	34.9	2,381	439	39.2	145	352	743
August	0.4	130	193	20.3	246	351	566
September	200	233	92.4	0.2	635	3,848	5,699

	1942-1943	1943-1944	1944-1945	1945-1946	1946-1947	1947-1948	1948-1949
October	2,137	155					
November	634	26.1					
December	2,752	116					
January	1,247	121					
February	1,303	251					
March	779	5,482					
April	402	14,060					
May	17,240	3,789					
June	7,982	972					
July	581	352					
August	86.1	561					
September	76.0	1,059					

Appendix B

OIL REFINERIES

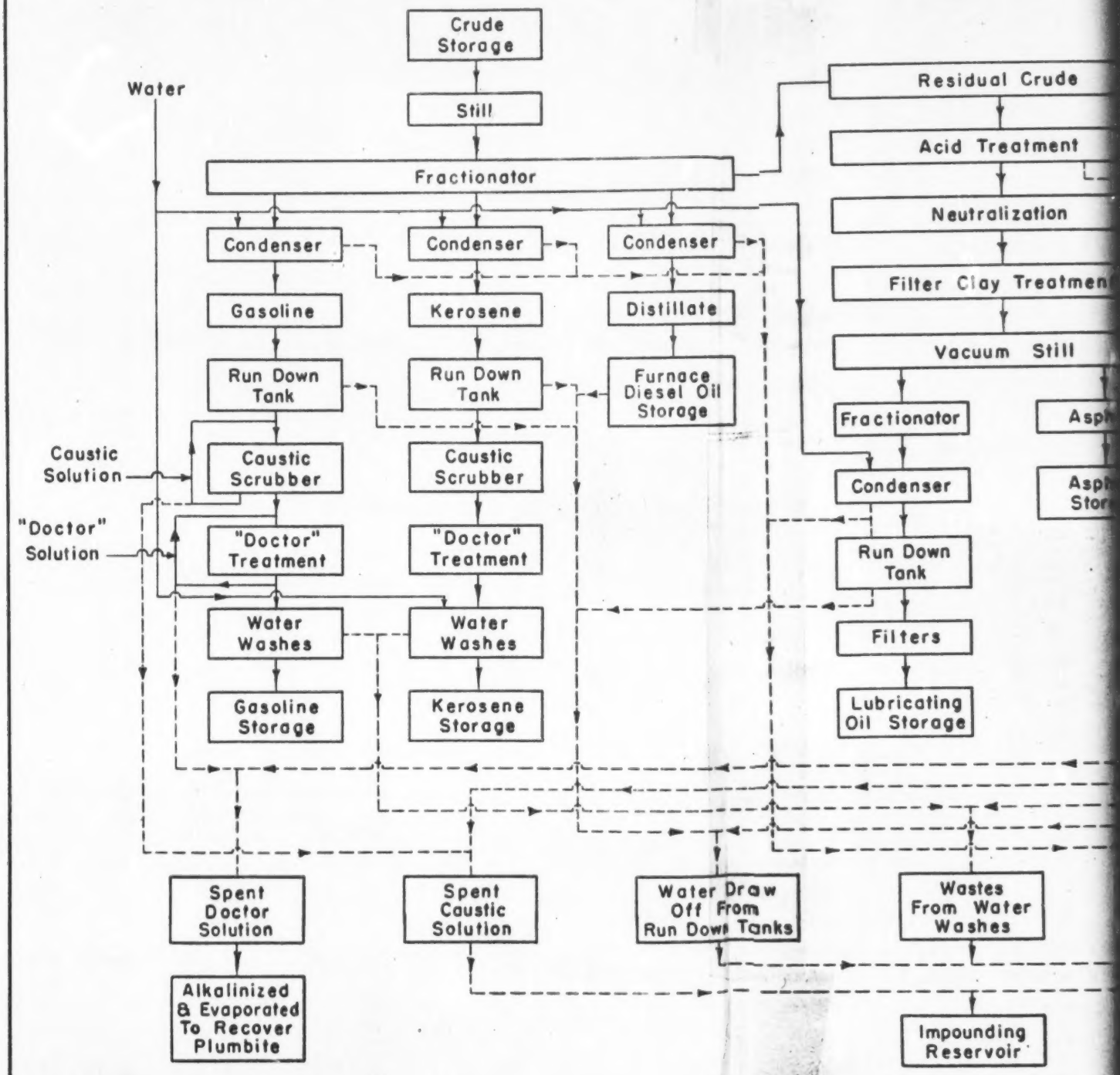
A general survey was made of each of the three oil refineries: that of the Standard Oil Company at Neodesha, and the Sinclair Refining Company and the Co-operative Refinery Association plants at Coffeyville, Kansas. At the two latter refineries, special investigations, involving the measurement of the flow and the collection and analyses of samples of the wastes discharged to the river, were also undertaken.

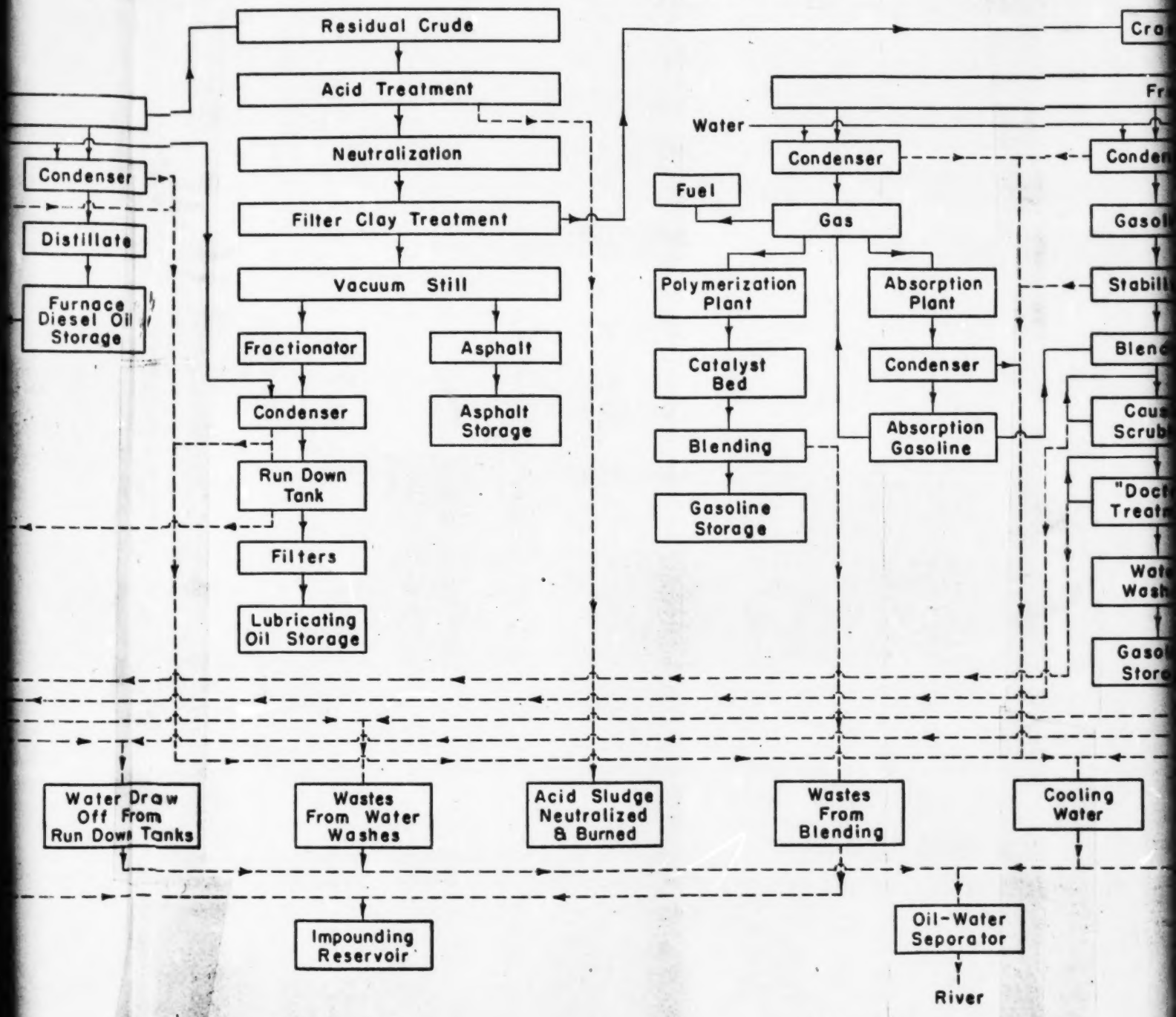
Sinclair Refining Co., Coffeyville, Kans.

The Sinclair Refining Company's Coffeyville refinery processes 15,000 barrels (42 gallons per barrel) of crude and about 250 barrels of reclaimed oil per day. The plant operates 24 hours per day, 365 days per year, and employs approximately 600 persons, 50 of whom are office workers. There is little, if any, seasonal variation in production. However, production does vary in accordance with quotas established by the parent Sinclair Oil Company.

The principal raw materials, other than crude oil, are water, sulfuric acid, caustic soda and plumbite. Industrial water consumption is estimated at 3.6 m.g.d. It would be much higher were it not for the ponding and recirculation of cooling water.

The flow diagram, Figure 3, shows the principal steps involved. The crude oil from the producing fields is piped to large storage tanks. Next it is distilled in the straight-run still and the vapor passes to a fractionating tower where the lighter products, gasoline, kerosene, distillate and the gas-oil cut, are separated by withdrawal from different levels, and the fractionator bottoms are retained for further treatment. The gas-oil cut goes to the cracking still, while the crude gasoline, kerosene, and light fuel oil are separately condensed and collected in run-down tanks, after which they are purified by treatment in a caustic scrubber and/or a "Doctor" treatment unit, and finally by water washes.


Crude Storage
Still
Fractionator
Water
Residual Crude
Acid Treatment
Neutralization
Filter Clay Treatment
Vacuum Still
Fractionator
Condenser
Condenser
Condenser
Condenser
Gasoline
Kerosene
Distillate
Run Down Tank
Run Down Tank
Furnace Diesel Oil Storage
Caustic Solution
Caustic Scrubber
Caustic Scrubber
"Doctor" Solution
"Doctor" Treatment
"Doctor" Treatment
Run Down Tank
Water Washes
Water Washes
Filters
Gasoline Storage
Kerosene Storage
Lubricating Oil Storage
Spent Doctor Solution
Spent Caustic Solution
Water Draw Off From Run Down Tanks
Wastes From Water Washes
Alkalinized & Evaporated To Recover Plumbite
Impounding Reservoir


Residual Crude
Acid Treatment
Neutralization
Filter Clay Treatment
Vacuum Still
Fractionator
Asphalt
Condenser
Asphalt Storage
Run Down Tank
Filters
Lubricating Oil Storage
Condenser
Distillate
Furnace Diesel Oil Storage
Water
Condenser
Fuel
Gas
Polymerization Plant
Absorption Plant
Catalyst Bed
Condenser
Blending
Absorption Gasoline
Gasoline Storage
Water Draw Off From Run Down Tanks
Wastes From Water Washes
Acid Sludge Neutralized & Burned
Wastes From Blending
Cooling Water
Impounding Reservoir
Oil-Water Seporator
River

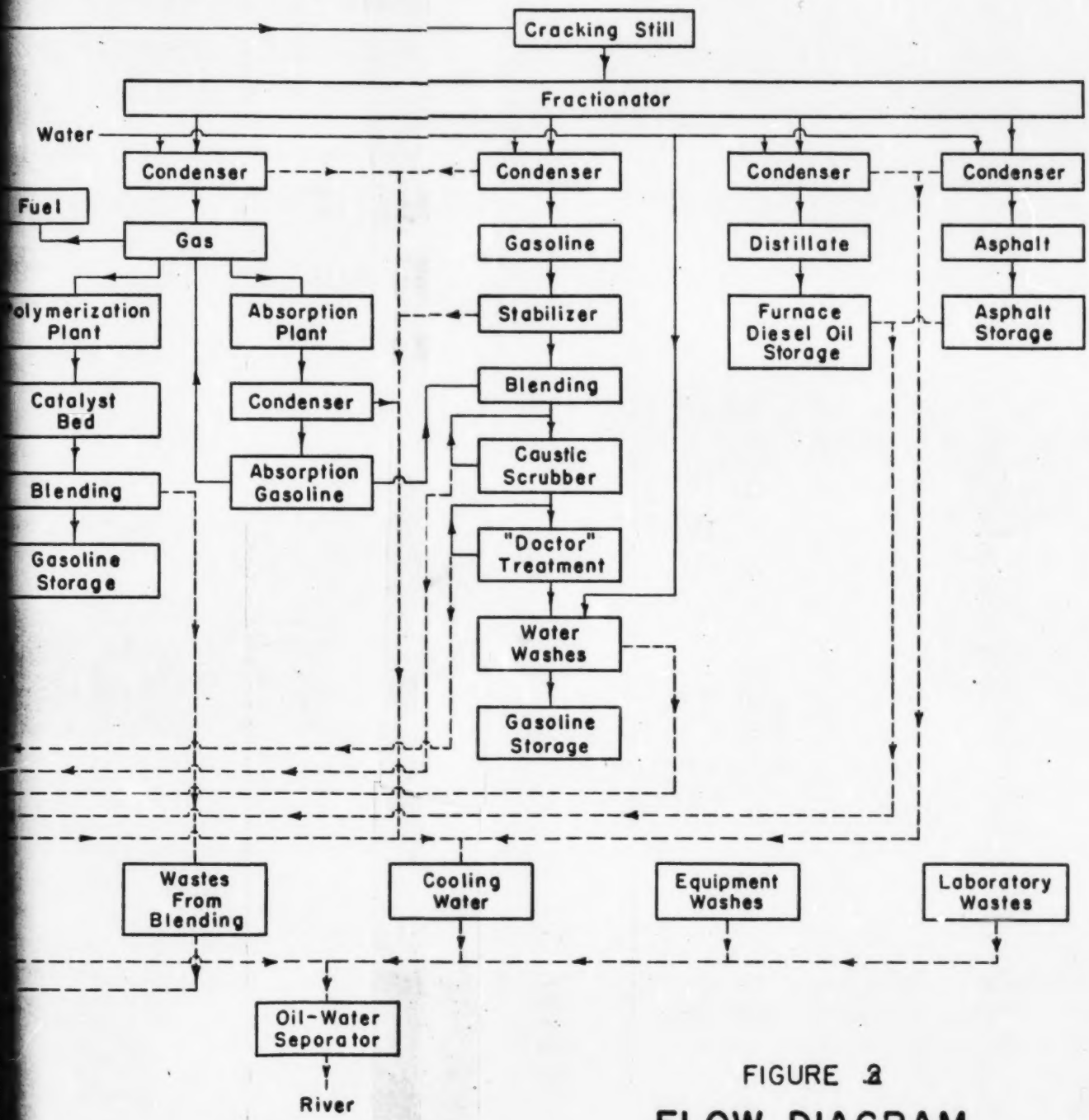


FIGURE 2

FLOW DIAGRAM

COOPERATIVE REFINERY ASSOCIATION

COFFEYVILLE, KANSAS

The caustic scrubber treatment consists of a caustic soda solution being injected into and thoroughly mixed with the gasoline or other product. The mixture then flows into a vertical tank, where the gasoline rises to the top and is drawn off for further treatment, and the caustic soda solution, containing such impurities as hydrogen sulfide, mercaptans, phenols and cresols, is drawn from the bottom and recirculated by injecting it into incoming gasoline. Eventually, after several weeks, the caustic solution becomes so contaminated with impurities that it is no longer usable.

The "Doctor" treatment process is similar, except that an alkaline sodium plumbite solution is used to remove the impurities. After long usage the "Doctor" solution becomes so heavily contaminated that it is removed, alkalinized and evaporated to recover the sodium plumbite.

Finally, the gasoline or other product is water-washed to remove any remaining caustic, "Doctor" solution, etc. After intimate mixing of the water and gasoline, the water is settled by gravitation and discharged to waste, while the gasoline goes to storage or the blending units.

The fractionator bottoms are treated by vacuum distillation to produce lubricating oil. This process is similar to that employed for producing the straight-run gasoline, etc., except that the impurities are removed from the lubricating oil by an acid treatment, followed by agitation with fuller's earth and filtration.

The gas-oil cut from the straight-run condensers passes to the cracking still and thence to the fractionators, where the heavy fuel oil is retained and the gasoline and furnace fuel oil are separated and condensed. The crude gasoline is treated to remove propane and butane gas, after which it is purified by a process identical with that used for the straight-run gasoline.

The products and their average daily production are: gasoline, 6,000 bbl.; fuel oil, 2,700 bbl.; lubricating oil, 1,425 bbl.; and kerosene and light fuel oil, 3,450 bbl.

The waste discharge consists largely of cooling water, condensed water drawoff from the run-down tanks, and the water washes used in the final purification treatment for gasoline, kerosene and light fuel oil. Other wastes, of relatively small volume, which must be disposed of at varying intervals, are caustic solution from the scrubbers, "Doctor" solution, and sludge from acid treatment.

At this particular plant the spent caustic soda solution is impounded, the acid sludges are mixed with fuel oil and burned, and the spent "Doctor" solution is alkalized and evaporated to recover the sodium plumbite.

The wastes reported to be highest in phenol content, the water washes which follow the "Doctor" treatment for both the straight-run and cracked gasoline, are collected in a holding tank, acidified and heated by steam to drive off most of the phenol or phenolic type components. These treated wastes are then impounded.

The washes following the "Doctor" treatment of the kerosene and the caustic treatment of the light fuel oil are collected separately and treated by passage through a mud trap, an oil-water separator, a neutralizing pit and slow-sand type filters. These wastes and the sanitary sewage effluent from the septic tanks are jointly discharged through a sewer outlet to the river.

The balance of the wastes, which are composed of the excess cooling water, drawoff from the run-down tanks, steam boiler drawoffs and the contact digestion steamings, flow through a mud trap, a large oil-water separator, an oil separator settling tank and 3 hay basket screens into a ditch and thence into the river.

A field survey showed three outlets from which wastes might be discharged to the river. One was the overflow from a lagoon or impounding reservoir, which was apparently used to withhold sludge from the boiler water softening, etc. Overflow from this source was rare, and in the few cases noted the quantity was extremely small.

The second was the sewer outlet discharging the effluent from the sand filters and the septic tank. The flow was estimated at approximately 72,000 gal. per day (50 g.p.m.). Since analyses of two grab samples showed phenol concentrations of 315 and 1040 p.p.b., the importance of this waste, at least as far as phenol is concerned, was considered insignificant when compared to that discharged through the main effluent channel.

A 42-inch rectangular, suppressed weir was installed in the main effluent channel. Flow measurements were taken and samples collected hourly over three 24-hour periods and one 18-hour period. Samples for analysis for phenol were preserved with copper sulfate. Prior to analysis, the hourly samples were composited volumetrically in proportion to waste flow.

The results of the analytical determinations are given in Table 3 of the main report, and certain summary data showing a comparison between this and Co-operative refinery are shown in Table 9.

The average flow was 2.1 m.g.d., or 14,000 gallons per 100 barrels of crude, and the mean phenol concentration was 555 p.p.b. The phenol discharged to the river averages 9.7 pounds per day, or only 0.067 pounds per 100 barrels of crude oil processed.

The 5-day B.O.D., as computed from the waste flow and strength, amounts to 765 pounds per day, or a sewered population equivalent of 31 persons per 100 barrels of crude. When computed from the stream flow and the change in oxygen balance, the 5-day B.O.D. discharged to the river is 2,180 pounds per day, or 87 persons per 100 barrels of crude. This difference may be explainable through the oxygen demand exerted by accumulated sludge deposits. However, it is not unlikely that the increase in indicated B.O.D. resulted from the increased dilution of the waste. For example, it was noted that the indicated B.O.D. of river water samples, as determined using a 50% dilution, was frequently as much as 200 to 300 per cent of that obtained when no dilution was used.

Co-operative Refinery Association, Coffeyville, Kansas

The Coffeyville Co-operative Refinery Association plant processes 13,300 barrels of crude and from 250 to 300 barrels of reclaimed oil per day. It operates 24 hours per day, 365 days per year, and employs 465 persons, 35 of whom are office workers. Operation is very uniform throughout the year.

The principal raw materials, other than oil, are water, acid, caustic soda, and plumbite. Water consumption is estimated at 2.9 m.g.d. It is relatively low, due to the recirculation of cooling water.

The processes employed include straight distillation, vacuum distillation and cracking. These processes are essentially the same as those described for the Sinclair Oil Company plant. Figure 4 shows the flow diagram for the plant.

The principal products and their quantities are: gasoline, 5000 to 6000 bbl./day; fuel oil, about 2000 bbl./day; lubricating oil, 1400 to 2000 bbl./day; and kerosene and asphalt, approximately 4000 bbl./day.

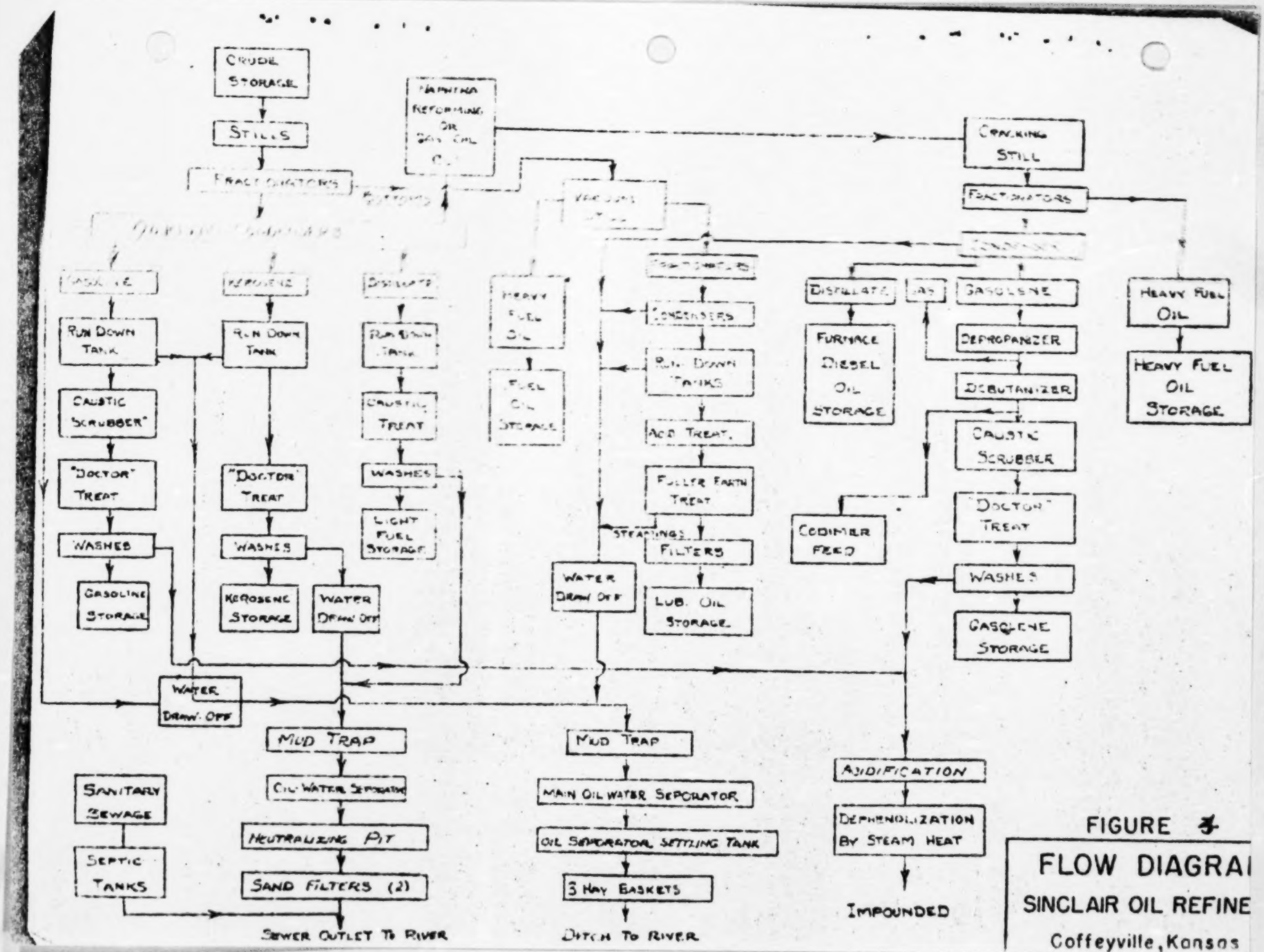


FIGURE 3

FLOW DIAGRAM

SINCLAIR OIL REFINERY

Coffeyville, Kansas

Table 9 - Verdigris River Investigation - Summary of Data on Oil Refineries and Results of Analyses of Their Wastes.

Refinery and date of test	Employees per 100 bbl crude oil	Wastes, gals. per 100 bbl. crude oil	Analyses		Sewered population equivalent(B.O.D.) per 100 bbl. crude	Phenol, lb. per 100 bbl. crude oil
			Phenol p.p.b.	B.O.D. p.p.m.		
Sinclair Oil Co.						
9/21-22		16,200	510	--		0.069
9/23		11,800	495	--		.049
9/28-29		14,600	680	32	23	.083
9/30-10/1		13,200	535	57	38	.059
Average	3.6	14,000	555	45	31*	.065
Co-op. Ref. Asso.						
9/21-22		7,450	1,330	--		.084
9/23-24		7,520	1,220	--		.077
9/28-29		9,180	1,600	39	18	.122
9/30-10/1		9,100	1,610	34	16	.122
Average	3.3	8,350	1,440	36	17**	.101

* Sewered population computed from stream flow and change in oxygen balance = 87 persons.
** Sewered " " " " " " " " " " = 32 persons.

The principal wastes and methods of their treatment and/or disposal are:

(1) Sludge from acid processes is neutralized with caustic and burned as fuel.

(2) Spent caustic from the scrubber is discharged to impounding reservoirs.

(3) The spent "Doctor" solution is treated and evaporated to recover plumbite.

(4) Excess cooling water and all other wastes are discharged through a series of oil-separating ponds to the Verdigris River. Included in these wastes are water wastes from run-down tanks, water washes following caustic and "Doctor" treatments, equipment washes, and laboratory wastes.

A new American Petroleum Institute type oil-water separator tank, 180 feet long, 35 feet wide and a liquid depth of about 7.5 feet, was under construction and should by now be in use.

For the purpose of flow measurement, a 36-inch Cipolletti weir was installed in the main waste channel. Samples were collected hourly and composited volumetrically in proportion to flow. Copper sulfate was used as a preservative for those for phenol determination.

Analytical data may be found in Table 3 of the main report, and a comparison of certain data for this and Sinclair refinery is given in Table 9. The average flow was 1.11 m.g.d., or 8,350 gallons per 100 barrels of crude. The phenol content averaged 1,440 p.p.b. The phenol discharged to the river was 13.4 pounds per day, or only 0.101 pounds per 100 barrels of crude.

The waste discharged to the river had an indicated 5-day B.O.D. of 370 pounds per day, but when computed from stream flow and the decrease in oxygen balance, it was 709 pounds per day. The sewered population equivalent in the first case would be 17 persons per 100 barrels of crude; and in the latter case 32 persons.

Standard Oil Co. of Indiana, Neodesha, Kans.

The Standard Oil Company of Indiana plant at Neodesha, Kansas, processes 9000 barrels of crude oil per day. It operates 24 hours a day, 365 days a year, without appreciable variation, and employs 225 persons, of whom 205 are plant employees.

This plant utilizes the usual raw materials and processes to produce 4,500 bbl./day of gasoline, 2,700 bbl./day of fuel oil, and 1,800 bbl./day of kerosene and other products.

A total of 5 m.g.d. is pumped from the Fall River, 4 m.g.d. of which is used for cooling, after which it is returned to the river. Approximately one m.g.d. is process waste water, which is pumped to large shallow storage reservoirs covering 85 acres. The Plant Manager of the refinery stated that these reservoirs have not overflowed for several years.

No special studies were made at this refinery.